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RADIOCARBON DATING AND POLLEN ANALYSES OF TWO PEAT BOGS IN THE PLITVICE NATIONAL PARK

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Radiocarbon measurements confirmed the age of peat samples from two cores taken near Lake Prošće in the Plitvice National Park, previously dated on the basis of pollen analyses. Palynological and radiocarbon analyses helped to reconstruct the history of peat bogs and tufa barriers of Lake Prošće. The vegetation sequences as well as tufa growth in Holocene are discussed in some detail.

Introduction

Two parallel sets of cores were taken for radiocarbon dating and pollen analyses in the area of the Plitvice National Park on the shores of Lake Prošće. In this way any ambiguity concerning the depth of contemporaneous samples was eliminated. The cores for radiocarbon analyses were stored at the Research Centre of Plitvice National Park and in ^{14}C laboratory of the Rudjer Bošković Institute, Zagreb, whereas pollen analyses were performed at the Scientific Research Center of the Slovene Academy of Sciences and Arts, Ljubljana.

The results of palynological research were published (Culiberg and Šercelj 1981) and reader is referred to the cited paper for a detailed explanation of the pollen diagrams shown in figs. 1 and 2 and the vegetational sequences in the region investigated.

The main purpose of this article is to correlate the age of samples as derived from the successive stages in the vegetation with their radiocarbon age.

Methods

Method of age measurement of biogenic materials by means of radiocarbon was developed by W. F. Libby in the early fifties (Libby 1955). Radioisotope ^{14}C is formed in upper layers of the atmosphere by interaction of thermalized neutrons produced by cosmic rays with nitrogen nuclei according to the relation:

$$^{14}_{7}N\,(n,p)\,^{14}_{6}C$$

Carbon atoms interact with atmospheric oxygen to form CO_2, which is evenly distributed in the biosphere *via* photosynthesis and food chains. Even though ^{14}C decays with half-life of 5570 years, the specific activity of ^{14}C in live matter is always constant because the decayed atoms are constantly replaced with new ^{14}C atoms from the atmosphere.

After the death the amount of ^{14}C in organisms is not compensated by those from atmosphere and begins to decrease according to exponential law:

$$N = N_0 \exp(-\ln 2 \; t/T_{1/2})$$

where $T_{1/2}$ is ^{14}C half life. By measuring the remaining amount of ^{14}C atoms, *i. e.* by measuring the activity of the sample, the age *t* passed since the death of the living matter can be calculated according to:

$$t = \frac{1}{\lambda} \ln \frac{A_0 - A_b}{A_s - A_b}$$

Where A_s is activity of the sample, A_0 is activity of the standard sample (which corresponds to the recent activity of the atmosphere). A_b is background counting rate of the counter and λ is decay constant ($\lambda = \ln 2/T_{1/2}$).

By ^{14}C method samples containing organic carbon, such as bones, charcoal, peat, soil carbon etc., as well as inorganic samples containing carbon of biogenic origin, such as speleothems, tufa, secondary calcareous sediments, shells and groundwater can be measured up to the age of 40 000 years.

Peat samples were prepared by the standard method used in most radiocarbon laboratories (Srdoč et al. 1971). Samples were boiled for 1 hr in a 4% solution of HCl, washed in distilled water, shortly treated with 4% solution NaOH, washed in distilled water to neutrality and dried at 95 °C. Prepared samples were burned in a stream of oxygen. Carbon dioxide thus obtained was purified by passing over silver wool, heated at 450 °C. CO_2 was collected in liquid nitrogen trap and converted into methane by reaction with hydrogen at 450 °C over ruthenium catalyst. Methane was used for proportional counter filling after careful purification which included vacuum distillation and removal of traces of impurities.

After storing the counting gas for about 14 days to allow shortliving nuclides (*e. g.* radon) to decay, a proportional counter was filled with the gaseous sample and measured for 24 hours.

Fig. 1. Pollen diagram from peat bog of Kmezina bara

Fig. 2. Pollen diagram from peat bog of Luličina bara

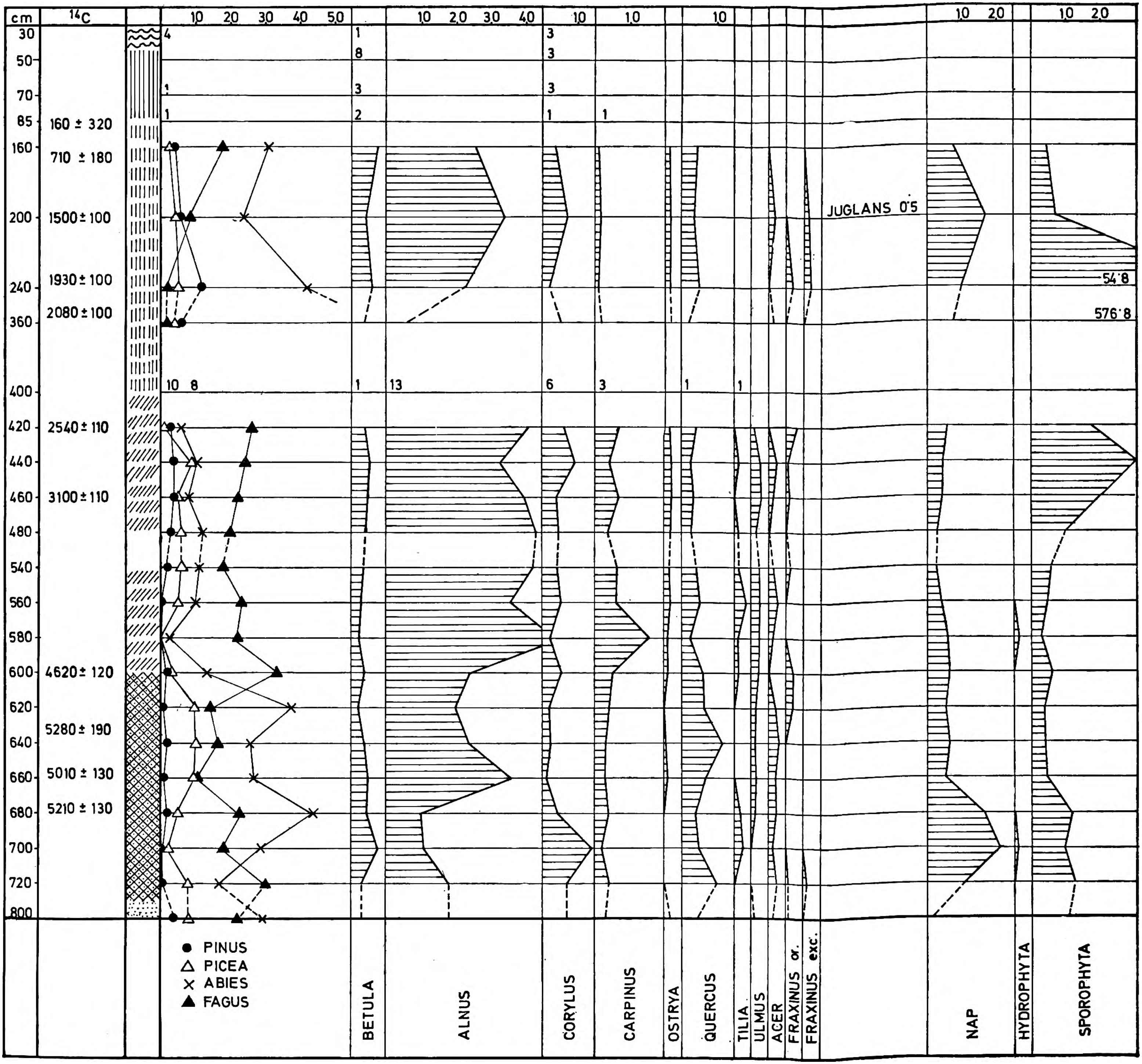
cm
14C
160 ± 320
710 ± 180
1500± 100
1930± 100
2080± 100
2540± 110
3100± 110
4620± 120
5280± 190
5010 ± 130
5210 ± 130
JUGLANS 0'5
54'8
576'8
PINUS
PICEA
ABIES
FAGUS
BETULA
ALNUS
CORYLUS
CARPINUS
OSTRYA
QUERCUS
TILIA
ULMUS
ACER
FRAXINUS or.
FRAXINUS exc.
NAP
HYDROPHYTA
SPOROPHYTA

Fig. 1.

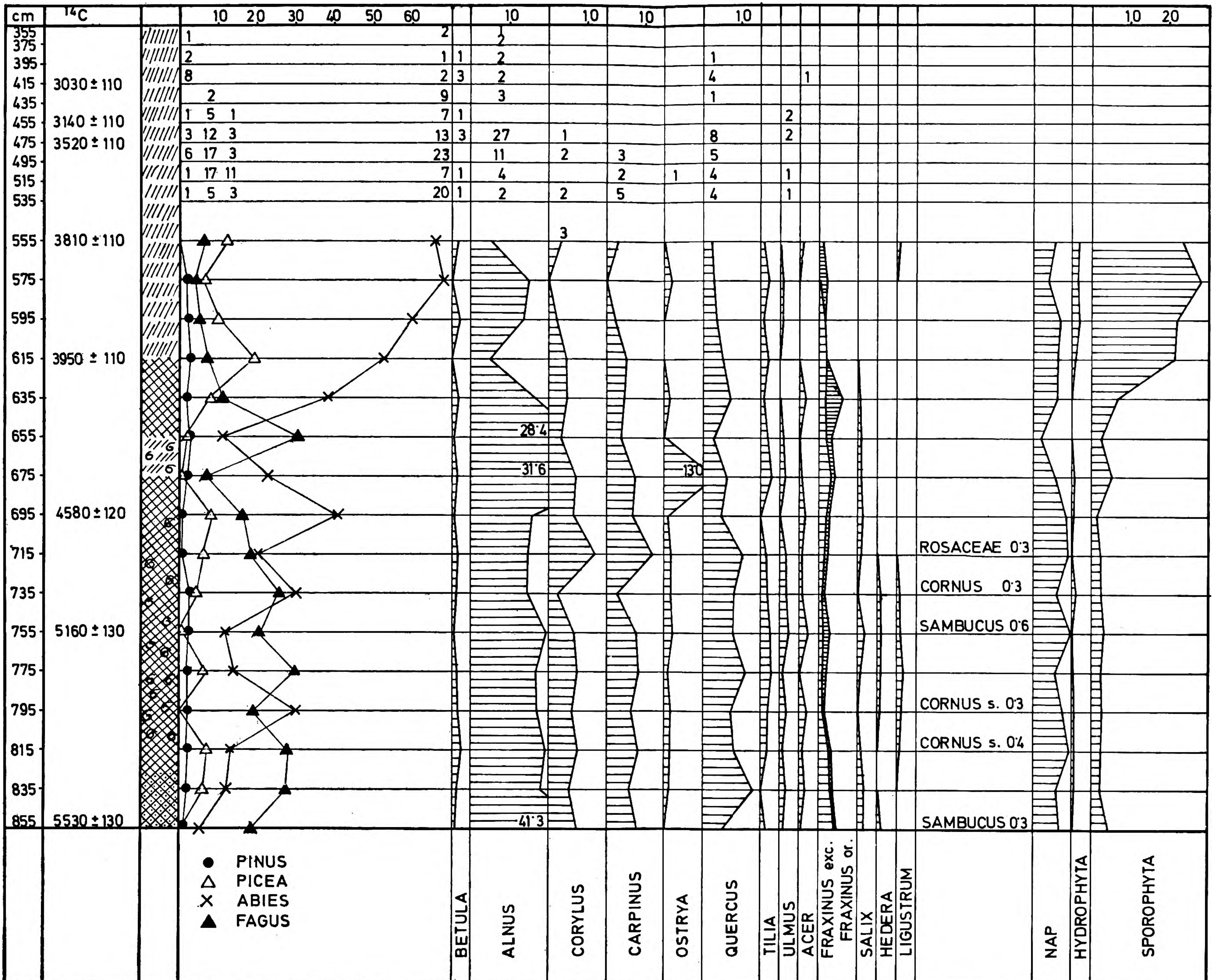
cm
^{14}C
3030 ± 110
3140 ± 110
3520 ± 110
3810 ± 110
3950 ± 110
4580 ± 120
5160 ± 130
5530 ± 130
PINUS
PICEA
ABIES
FAGUS
BETULA
ALNUS
CORYLUS
CARPINUS
OSTRYA
QUERCUS
TILIA
ULMUS
ACER
FRAXINUS exc.
FRAXINUS or.
SALIX
HEDERA
LIGUSTRUM
ROSACEAE 0·3
CORNUS 0·3
SAMBUCUS 0·6
CORNUS s. 0·3
CORNUS s. 0·4
SAMBUCUS 0·3
NAP
HYDROPHYTA
SPOROPHYTA

Fig. 2.

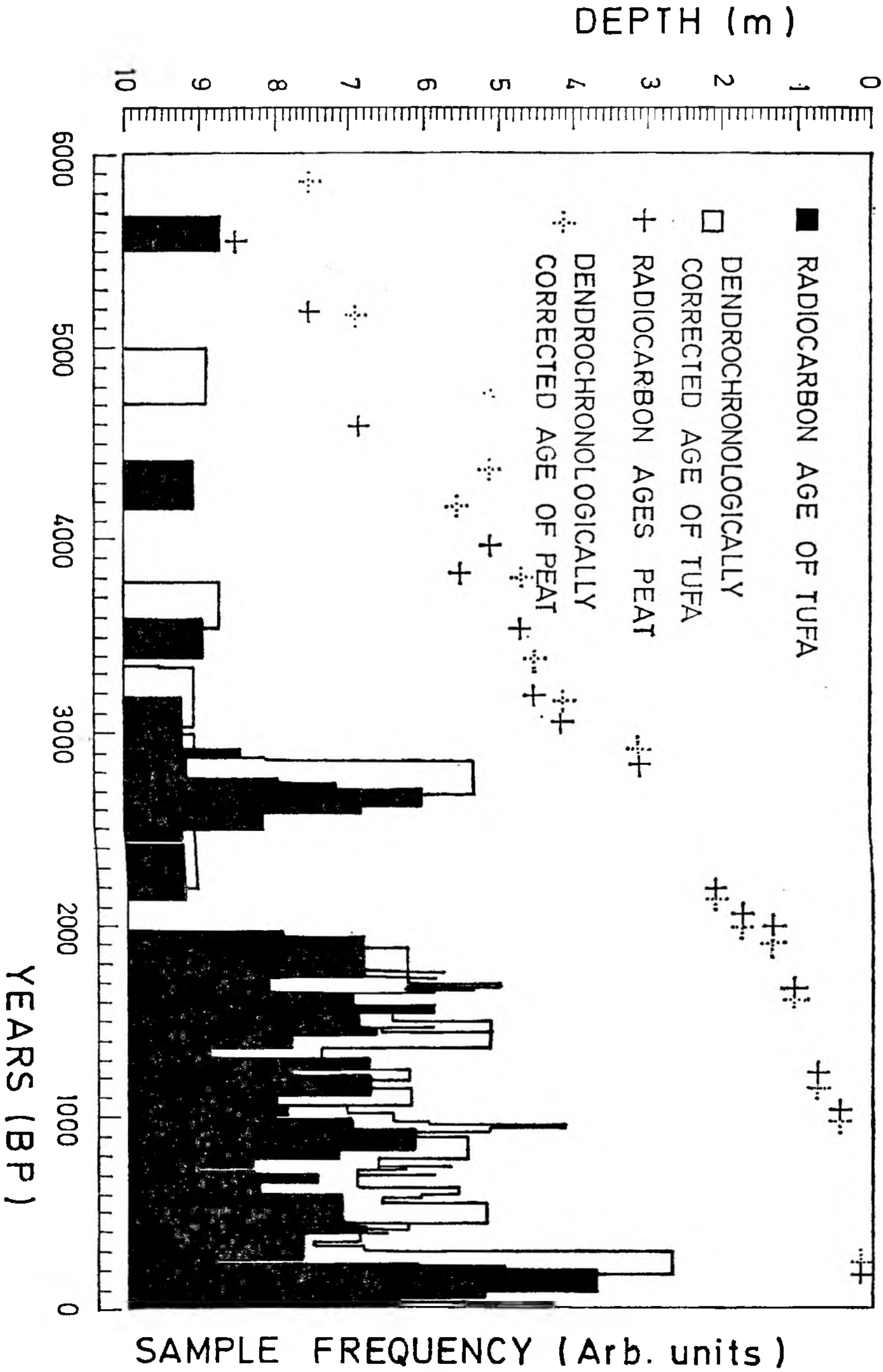

Fig. 3. Radiocarbon age of peats *vs* depth; right side of the plot: Frequency of randomly collected tufa samples *vs* ^{14}C age.

Results and Interpretation

The results of radiocarbon dating of peat samples from core Luličina bara are shown in fig. 3, together with the results of tufa dating from the area surrounding the Lakes. The age of peat is given in conventional radiocarbon years before present (BP) taking year 1950 as the starting point and ^{14}C halfe life as 5730 years, whereas the age of tufa has been calculated on the basis of initial activity of dissolved Ca-bicarbonate in stream water (Srdoč et al. 1983). Dendrochronological corrections of radiocarbon age, shown in fig. 3 as dotted crosses for peat and open bars for tufa, are considered the closest approximations to real calendar age. The frequency of occurence of tufa samples *vs.* age, shown on the right side of the plot in fig. 3. is the result of *quasi* random sampling of 60 tufa samples. The coincident beginning of tufa and peat formation in Holocene at *ca* (6200±200) years B. P. may be explained by the possibility that tufa formation and intensive vegetation started simultaneously when climatic conditions at this altitude (640 m) became favorable for both processes.

The oldest palynologically determinable age has been defined by the fact that in both pollen diagrams a well developed *Abieti-Fagetum* predominates. In this region the *Abieti-Fagetum* appeared not later than 7000 years B. P., probably even earlier, considering that in the southeastern Alps, on the Jelovica Plateau at an elevation of 1100 m a. s. l., the first appearance of *Abieti-Fagetum* has been dated by the radiocarbon method to (6960 ± 90) years B. P. (Z-577) (Culiberg et al. 1981, Srdoč et al. 1982) and correspondingly on the Pokljuka Plateau to (6890 ± 45) years B. P. (Grn-5845) (Šercelj 1971). These data are regarded for pollen diagrams from the Plitvice Lakes as *terminus post quem non.*

When drawing parallels between the two pollen diagrams from the Plitvice Lakes, it becomes evident that the layers of peat from the same depth are not exactly of the same age, their growth rate being different too.

The peat bog of Kmezina bara started to grow on a dolomitic base when the water level of Prošće submerged this part of the valley. This occurred when the tufa barrier reached 631 m a. s. l., *i. e.* 8 m below the present lake surface (639 m). This is a direct proof that the barrier of Prošće grew 8 m over the last 5500 years.

The bottom of the peat bank of Luličina bara was not reached by boring. The section of the profile below 855 cm (at which depth the radiocarbon age is (5530 ± 130) years B. P.), is presumably several hundreds years older.

The sudden rise of the curve of *Abies* in the pollen diagram of Luličina bara at the depth of 635 cm has been correlated with a similar rise in the pollen curve of *Abies* in the area of Ljubljansko Barje at the end of Eneolithic lake-dwellers culture. This assumption seems to be correct, as the radiocarbon age of lake-dwellers culture turned out to be contemporary with the transitory rise of *Abies* curve in the region of Ljubljana. It has been supposed to be of anthropogenic origin, *i. e.* the consequence of an intense human impact upon the forest vegetation (Šercelj 1955, Culiberg and Šercelj 1978). Given that in the area of the Plitvice Lakes Eneolithic sites were found, the human influence upon the local vegetation could be the cause of the sudden spread of *Abies* at the same time. This assumption was confirmed by the radiocarbon dating [(3950 ± 110) years B. P.] of Luličina bara, but not for Kmezina bara. In the gap between 540 and 480 cm the missing rise of *Abies* curve could be expected which falls exactly into the time--interval between 4620 and 3100 radiocarbon years. The section between 700 and 620 cm corresponds to the section between 735 and 675 cm at Luličina bara. Also, from these two sections the correlation in vegetation is proved to agree with the radiocarbon date.

This is not valid for the lowest horizons. The eastern shore was reached by water level as early as (5530 ± 130) years B. P.. Since then the growth of peat continued rather regularly up to the level of 615 cm. From the level of 550 cm upwards in both profiles, which according to ^{14}C measurements are nearly of the same age, the peat is heavily weathered and so are the pollen grains. The results of pollen analyses in the upper section are not reliable for the vegetational history, and for this reason chronology of peat layers depends exclusively on radiocarbon measurements.

Conclusion

Pollen and radiocarbon analyses of two peat bogs near Lake Prošće helped to reveal details concerning the growth of peat banks and tufa barriers.

As the peat at Luličina bara consists mainly of *Hypnaceae,* a moist or marshy habitat is expected to have existed there, which enabled peat growth. At present this place is dry and situated one to two meters above the lake level, which caused weathering and shrinkage of peat. This allows the assumption that by the end of Eneolithic the water level should have been at least 2 meters higher than it is today, dammed up by the barrier which was found near the Matica estuary. The barrier is presently 2 to 3 m below the Prošće water level, eroded and lowered by high waters.

The history of the growth of tufa barriers since the end of Pleistocene remains unknown so far. Probably the barrier continued to grow on top of older tufa barriers of interglacial or interstadial periods, or even on a Mesozoic bedrock. One must keep in mind that during Pleistocene glacial periods the destruction of tufa took place, rather than its formation.

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Sažetak

RADIOKARBONSKO DATIRANJE I POLENSKE ANALIZE DVAJU TRESETIŠTA U NACIONALNOM PARKU »PLITVIČKA JEZERA«

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Starost 16 uzoraka treseta iz dviju bušotina s područja Prošćanskog jezera u Nacionalnom parku »Plitvička jezera« izmjerena je metodom radioaktivnog ugljika ^{14}C. Rezultati tih mjerenja, zajedno s rezultatima mjerenja starosti sedri s područja Plitvičkih jezera, prikazani su na histogramu, iz kojeg se vidi da rast treseta i sedri koincidira, ukazujući na povoljne klimatske prilike za oba procesa u razdoblju unatrag *cca* 6000 godina. Prikazane su polenske analize istih uzoraka koje pokazuju promjene u vegetaciji i rast sedrenih barijera u posljednjih 5 do 6 tisućljeća. Rezultati polenskih analiza predočeni su na dva dijagrama za bušotine na tresetištima Luličina i Kmezina bara u neposrednoj blizini Prošćanskog jezera. Upozoreno je na nagli porast vrste *Abies* koji koincidira s pojavom eneolitskih naselja u tom kraju, što može biti posljedica ljudske djelatnosti. Radiokarbonske analize treseta, sedre, drva iz sojenica i pougljenjenog drveća omogućile su apsolutno datiranje i kronološko povezivanje mnogih pojava na širem području naše zemlje.

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